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Shift work and sleep disorder comorbidity tend to go hand in hand

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ABSTRACT

Taking into consideration that shift work has a wide-ranging impact on circadian and sleep functioning, it seems likely that shift work increases the risk of a general sleep disturbance, spread out over a multitude of comorbid sleep disorders. The aim of the present study is to analyze and present the sleep disorder data of 250 shift workers and 971 permanent day workers, taken from a nationally representative sample. Additional data concerning duration, timing, and quality of sleep, daytime functioning and social/family variables were added to the analyses. The results showed that the shift workers experienced significantly more difficulties with the variability of their sleep times, reported more napping and considered themselves more as poor sleepers than the day workers. Most importantly, shift work, in comparison with day work, appeared associated with a significantly higher prevalence of the clinical, International Classification of Sleep Disorders' defined symptoms of nearly all main sleep disorders (including shift work disorder). For shift workers, the prevalence of a general sleep disturbance was 39.0% (95%CI 33.2 – 45.2), significantly higher than for day workers (24.6%, 95%CI 22.0 – 27.4). Moreover, shift workers were characterized by high levels of sleep disorder comorbidity. In addition, exclusively for shift workers, the prevalence of disordered sleep systematically decreased across decades of life and was considerably higher for single versus partnered shift workers. This study adds to the insight into the interacting factors that determine shift work coping and may play a role in occupational health interventions aimed at reducing sleep problems and thus improving the resilience and tolerance of the shift worker.

Introduction

A primary health complaint of many shift workers relates to the quality of their shifted sleep and is often expressed as difficulty with the onset, maintenance, and/or consolidation of their sleep, as well as sequelae such as moodiness or excessive sleepiness during the subsequent wake/work period (Akerstedt, 2003; Akerstedt et al., 2008; Costa, 1997; Monk et al., 2013). Most likely, these symptoms arise from the misalignment of circadian and homeostatic sleep-regulatory processes (Boivin & Boudreau, 2014; Van Dongen, 2006), although stressful social/family conditions of shift work are also very likely to contribute to the deterioration of sleep (Åkerstedt et al., 2011; Törnroos et al., 2017; Ulhoa et al., 2011). The close interaction among sleep homeostasis, circadian timekeeping, and social/domestic milieu has been aptly symbolized

as a triad of factors, influencing shift work coping ability (Monk, 1988). It follows that shift work conditions can be best understood on the basis of well-balanced knowledge in each of these three intertwined areas. It is the primary purpose of the present study to supplement existing knowledge of disturbed sleep in shift workers, especially regarding the prevalence of comorbid (co-occurring) sleep disorders.

Research on the prevalence, comorbidities, and other characteristics of shift work-related sleep complaints has concentrated mainly on Shift Work Disorder (SWD; (AASM, 2014) (Di Milia et al., 2013; Drake et al., 2004; Flo et al., 2012; Waage et al., 2009, 2014). Less information has been published about the possible link between shift work and the prevalence of other, comorbid sleep disorders. Acknowledging that shift work has

a wide-ranging impact on circadian and sleep functions (Bhatti et al., 2015; Costa et al., 2010; Smolensky et al., 2016; West & Bechtold, 2015), the effects of shift work can be expected to go beyond SWD and provoke a wide range of sleep disorders. The results of some studies support this suggestion. Garbarino and coworkers (Garbarino et al., 2002) constructed a self-assessment questionnaire with 14 items, covering insomnia, obstructive sleep apnea, restless legs and periodic limb movements, and hypersomnia. Comparing the results for shift-working police officers with the results for day-working colleagues, the authors observed higher prevalence rates for insomnia (25.9% versus 15.8%), hypersomnia (4.9% versus 2.2%), and restless legs and periodic limb movements (8.5% versus 4.2%). Signs of breathing-related disorders did not differ between the two groups. Discussing their results, these authors remark that "in many cases different types of sleep disorders were detected simultaneously, suggesting the presence of an extensive sleep-wake disturbance". Sleep disorder comorbidity was not quantified, however. In a group of nearly 5000 North American police officers, frequently working extended shifts and long work weeks, Rajaratnam and colleagues (Rajaratnam et al., 2011) observed that 40% screened positive for at least one sleep disorder, with 34% for obstructive sleep apnea, 7% for moderate-to-severe insomnia, 5% for shift work disorder, 2% for restless legs, and less than 1% for narcolepsy with cataplexy. Using nearly the same set of validated survey instruments, Barger and colleagues (Barger et al., 2015) reported that 37% of a large group of US firefighters screened positive for any sleep disorder including obstructive sleep apnea (29%), insomnia (6%), shift work disorder (9%), and restless legs syndrome (3%). Unfortunately, the last two studies did not compare shift workers with permanent day workers, nor did they calculate sleep disorder comorbidity.

The present research primarily aimed at evaluating the prevalence as well as the co-occurrence of the six main ICSD-defined sleep disorders (International Classification of Sleep Disorders, AASM 2005) in a nationally representative sample of 250 shift workers and 971 day workers, using their responses to a clinically validated sleep disorders questionnaire (Kerkhof et al., 2013).

Materials and methods

Sample

The dataset of the present study was extracted from an original database consisting of 2089 individuals, sampled from an ISO 26362-certified online research panel (https://www.motivaction. nl/en/research-method/online-market-research/ stempunt) of over 80.000 citizens of The Netherlands (total population in 2012: 16,730,000). An Internet panel is unlikely to give an accurate representation of the total population, however, as specific groups are liable to be either under- or over-represented. Therefore, a widely accepted remedy, that is, the propensity weighting technique (Lohr, 2010) was applied to the database, thereby correcting for standard demographic, socio-economic, and/or cultural characteristics, characteristics of non-Internet users, and also for non-responders. Propensity weighting scores were derived from the "Golden Standard" defined by Statistics Netherlands (CBS). As a result, a nationally representative sample of 2089 individuals aged 18 to 70 years was obtained (as a consequence of the applied weighting procedure, analyses may slightly differ in the number of subjects included).

In November 2012, data were collected in response to 44 questions coming from three self-report questionnaires (see assessment). Participants were also asked to indicate which category best-fitted their work schedule of the last 3 months. Response choices included: (1) "regular day shift;" (2) "regular early morning shift;" (3) "regular evening shift;" (4) "regular night shift;" (5) "rotating between morning, evening and night shifts;" and (6) "unemployed or retired." The total representative sample of 2089 individuals included a workforce of 1388 individuals, 310 of whom (prevalence: 22.3%, 95% CI (confidence interval): 20.2 – 24.6) were working some type of shift work. For the present study, the records of individuals younger than 21 years (N = 93) and older than 60 years (N = 323) were excluded, considering that the lifestyles of students and retired persons would warrant separate categories. Next, records were selected from the categories of permanent day workers (N = 971) and shift workers (N = 250), the latter consisting of a subgroup of rotating shift workers (N = 212), a subgroup of

permanent early morning workers (N = 30) and a subgroup of permanent night workers (N = 8). Because permanent early morning workers and permanent night workers rotate between regular (night) sleeping hours during their leisure periods and shifted sleeping hours during their work periods, these subgroups were included in the shift work group. Permanent evening workers (N = 31) were not selected, however, considering that regular evening work usually ends at 23:00 h and does not force evening workers to be awake during (part of) the 00:00 h–06:00 h night period.[1] In the Netherlands, rotating shift work predominantly follows a rapid clockwise rotation schedule.

Participants were paid by vouchers for a secluded web shop.

Assessment

Participants completed the following three sets of questions.

(1) Seven questions about demographic (age; gender), socio-economic (level of education; level of income), and psychosocial characteristics (partnership; children; housekeeping) (see Table 1). The latter three

Table 1. Socio-demographic characteristics (mean, SD: standard deviation) of day workers and shift workers, within the age range of 21–60 years, and drawn from a representative sample of 2089 persons. Data as indicated in first column. Pairwise comparisons were made using Pearson χ^2, t-test or Mann–Whitney U-statistic.

Socio-demographics	Day workers (n = 971)	Shift workers (n = 250)
Gender (% males)	51.8	52.4
Age (mean years (SD))	41.0 (10.4)	39.4 (11.9)
Partner (% partnered)[1]	79.2	69.3**
Child(-ren) at home (%)[2]	59.2	59.8
Education (mean rating 1–8)[3]	5.2 (2.1)	4.4 (1.9)***
Income (mean rating 1–7)[4]	4.2 (1.6)	3.9 (1.5)
Housekeeping (mean rating 1–3)[5]	2.0 (1.0)	2.1 (1.1)

1. Percentage of individuals with a regular partner
2. Percentage of individuals with 1 or more children living at home
3. Score 1 for no formal education, score 8 for Master degree
4. Score 1 for well below average, score 4 for average, score 7 for well above average
5. Score 1 for 'myself', score 2 for 'both of us equally', score 3 for 'my partner'.
** p < 0.01; *** p < 0.001

variables were included as representing social and family commitments.

(2) The Holland Sleep Disorders Questionnaire (HSDQ) (Kerkhof et al., 2013), recently evaluated as a comprehensive, clinically validated screening questionnaire (Klingman et al., 2016), is composed of ICSD-based clusters of sleep complaints/symptom descriptions that are specific to the six main sleep disorders. In responding to the 32 items (for formulations, see (Kerkhof, 2017)), subjects were asked to consider the past 3 months and rate their answer on a five-point rating scale ranging from "not at all applicable" to "applicable." Scoring of the HSDQ yields one factor score for a General Sleep Disturbance (GSD; internal consistency for this study: Cronbach's alpha 0.94) and six additional factor scores, one for each of the specific sleep disorders, that is, Insomnia (alpha 0.92), Parasomnia (alpha 0.85), Circadian Rhythm Sleep Disorder (CRSD; alpha 0.84), Hypersomnolence (alpha 0.78), Restless Legs Syndrome/Periodic Limb Movement Disorder (here referred to as Leg Movement Disorder, LMD; alpha 0.81), and Sleep-related Breathing Disorder (SBD; alpha 0.62). The GSD factor score can be considered a global, "transdiagnostic" index of disordered sleep, irrespective of specific sleep disorder characteristics. A factor score is a continuous variable that indicates an individual's relative ranking on a sleep disorder scale. If a factor score exceeds a specified cutoff value (threshold), that individual qualifies for a clinical diagnosis. Thus, by comparing GSD factor scores with a clinically validated cutoff value, a dichotomous GSD index was created, discriminating supra-threshold, clinically significant GSD scores from sub-threshold scores. Similar dichotomizing steps were taken for the other six factor scores. On the basis of supra-threshold scores, prevalence rates can be calculated, as formulated in the "Analyses" paragraph. The calculation of

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comorbidity was based on the number of crossings of the cutoff values for the six specific sleep disorders (Kerkhof et al., 2013). In case of two or more crossings, comorbidity was identified. In close keeping with the criteria of the ICSD-3, the shift workers in the present study were diagnosed with SWD symptoms if they met the HSDQ-Insomnia criterion and/or the Excessive sleepiness criterion. The latter was defined as a score of 4 ("usually applicable") or 5 ("applicable") for the HSDQ-item "During the day, I fall asleep involuntarily, especially in monotonous situations (e.g. during a boring TV show)." The grand average of this excessive sleepiness rating was 1.60 ± 0.93 (M ± SD) and correlated significantly with the HSDQ factor score for hypersomnolence (Pearson $r = 0.75$, $N = 1252$, $p < .001$).

(3) The third set included responses to five additional questions about Habitual sleep duration (number of hours), Subjective sleep need (number of hours), Number of naps per week, Morningness-Eveningness (M/E; 5-point rating), and Sleep quality (5-point rating). The M/E-score was calculated from the responses to the following two questions. Question 1: "Since early age I have a morningness preference. On days off I prefer to wake up at the same time as during a period of day work." Rating 1: not at all applicable; rating 5: applicable. Question 2: "Since early age I have an eveningness preference. On days off, I prefer to oversleep as long as possible." Rating 1: not at all applicable; rating 5: applicable. The M/E score was calculated as: (5 – response 1) + response 2, and varied between 1 and 9.

Considering their special relevance for a representative mapping of sleep-wake characteristics, the following seven HSDQ items were also analyzed as separate variables and included in the set of sleep-related variables presented in Table 2: (1) "I sleep poorly, because I don't manage to fall asleep at a normal hour and wake up at a normal hour in the morning," referred to as "Poor sleep & Inability to sleep at usual times" (this item loaded on the CRSD factor of the HSDQ); (2) "The time at which I fall asleep varies strongly from day to day," referred to as "Sleep onset variability" (this item loaded on the CRSD factor); (3) "The quality of my sleep is poor and I don't feel well rested in the morning," referred to as "Poor sleep quality & not well-rested in morning" (this item loaded on the Insomnia factor); (4) "I worry about the consequences of my poor sleep (e.g. for my health),"

Table 2. Mean (SD) scores for 12 sleep-related variables (range of variation), classified into 4 clusters.

Sleep-related variables	Day work (N = 971)	Shift work (N = 250)
*Sleep Duration***		
Sleep duration (4–9h)	6.92 (1.02)	6.89 (1.12)
Sleep need (4–9h)	7.50 (0.89)	7.42 (1.07)
Napping frequency (0–4 x/wk)	0.55 (0.97)	0.83 (1.09)**
*Sleep Timing****		
Morningness – Eveningness (1–9)	5.01 (2.34)	5.55 (2.29)**
Poor sleep & Inability to sleep at usual times (1–5)	1.59 (0.93)	1.95 (1.12)***
Sleep onset variability (1–5)	1.87 (1.0)	2.61 (1.28)***
*Sleep Quality**		
Good – poor sleeper (1–5)	2.49 (0.90)	2.64 (0.96)*
Poor sleep quality & not well-rested (1–5)	2.12 (1.14)	2.33 (1.20)**
Worry about health consequences poor sleep (1–5)	1.76 (1.01)	1.96 (1.08)**
Daytime Functioning		
Fatigue (1–5)	2.73 (0.97)	2.85 (0.98)
Sleepiness, bad mood, lack of energy, etc. (1–5)	2.55 (1.19)	2.65 (1.22)
Malfunctioning due to insufficient sleep (1–5)	1.90 (0.99)	1.98 (1.03)

*$p < 0.05$
**$p < 0.01$
***$p < 0.001$.

referred to as "Worry about health consequences poor sleep" (this item loaded on the Insomnia factor); (5) "During the day, I suffer from fatigue," referred to as "Fatigue" (this item loaded on the Insomnia factor); and (6) "Especially after a bad night, I suffer from one or more of the following consequences: fatigue, sleepiness, bad mood, poor concentration, memory problems, and lack of energy," referred to as "Sleepiness, bad mood, lack of energy, etc." (this item loaded on the Insomnia factor); (7) "Because of insufficient sleep, I don't function as well during the day," referred to as "Malfunctioning due to insufficient sleep" (this item loaded on the Insomnia factor). "Insufficient sleep" was defined as a sleep deficit (calculated by subtracting individual values of habitual sleep duration from individual values of subjective sleep need) of 1 hour or more (Hublin et al., 2001).

Analyses

The socio-demographic and sleep-related variables were statistically evaluated using the t-test, the Pearson χ^2 test, or the Mann–Whitney U-test. Where appropriate, prevalence ratios (PR) and their 95% CIs are presented. (Point) prevalence was calculated by dividing the number of individuals with a diagnosis (i.e. supra-threshold factor score) by the total number of individuals in the group studied and was expressed as a percentage. Univariate analysis of variance (ANOVA) was used to evaluate possible associations of the shift work versus day work factor with age-related variations of the factor scores for GSD, the six factor scores for specific sleep disorders, and the comorbidity scores. Multivariate analysis of variance (MANOVA) was applied to assess shift work versus day work differences between the four clusters of sleep-related variables. Binary logistic regression analyses were used to determine whether a selected set of predictor variables (gender, age, partnership, children, insufficient sleep, napping, and M/E-propensity) contributed to the odds of a general sleep disturbance and to compare the number and the size of the statistically significant odds ratios for shift workers and day workers. SPSS 24 for Windows was used for all statistical analyses.

Results

Sample characteristics

As specified in Table 1, pairwise comparisons revealed that the present sample of shift workers did not differ significantly from the sample of day workers with respect to gender, age, number of children, level of income, and participation in housekeeping. Statistically significant differences were observed with respect to partnership and education, that is, shift workers were more likely to be single and reported relatively lower levels of education. As partnership may serve as a proxy for the social/family factor in the "work-strain triad" (see Introduction), its potential impact is evaluated in the section on disordered sleep.

Clusters of sleep variables

The individual sleep variables, introduced in the Methods section, were conveniently arranged into four clusters, each cluster containing three variables with roughly similar sleep characteristics. The clusters are labeled as Sleep duration, Sleep timing, Sleep quality, and Daytime functioning (see Table 2).

Results revealed that the following clusterwise comparisons had a significant outcome: Sleep Duration ($F(3,1241) = 4.30$, $p < 0.01$), Sleep Timing ($F(3,1294) = 35.41$, $p < 0.001$), and Sleep Quality ($F(3,1294) = 3.24$, $p < 0.05$). The results of the between-group comparisons for the individual variables of these three clusters are indicated in Table 2. In brief, the shift workers experienced significantly more difficulties with the variability of their sleep times, reported more napping and considered themselves more as poor sleepers than the day workers. Daytime functioning did not reliably differ between the two groups.

Disordered sleep

For both groups of workers, Table 3 presents the observed prevalence rates (and their 95% CIs) for a general sleep disturbance, the six specific sleep disorders and comorbidity. For nearly all these prevalence estimates (except SBD), shift work appeared to be associated with significantly higher values than day work. Note that the

Table 3. Prevalence rates (95% Confidence interval). Asterisk (column 3) indicates a significant outcome of a Pearson χ^2-test for shift workers versus day workers, respectively, for age (column 4; p < .05). Column 4: D = Day work, S = Shift work.

Sleep Disorders	Day Workers	Shift Workers	Age categories 21–30 → 51–60
General Sleep Disturbance	24.6 (22.0–27.4)	39.0* (33.2–45.2)	D*: 28.8 – 17.4 – 30.6 – 21.0 S*: 52.2 – 45.2 – 26.5 – 30.2
Insomnia	4.9 (3.8–6.5)	8.8* (5.9–13.0)	D*: 6.3 – 0.8 – 7.5 – 5.6 S*: 11.9 – 8.1 – 7.4 – 7.5
Circadian Rhythm Sleep Disorder	2.8 (1.9–4.1)	9.2* (6.2–13.4)	D*: 2.1 – 0.8 – 4.9 – 2.8 S: 9.0 – 11.3 – 10.3 – 5.6
Parasomnia	3.8 (2.8–5.2)	10.8* (7.5–15.4)	D: 5.2 – 5.4 – 2.9 – 2.3 S*: 20.9 – 13.1 – 2.9 – 3.7
Hypersomnolence	3.7 (2.7–5.1)	8.8* (5.9–12.9)	D: 6.3 – 2.7 – 2.9 – 3.3 S*: 17.9 – 6.5 – 4.4. – 5.6
Leg movements	9.6 (7.9 – 11.6)	16.8* (12.7 – 21.9)	D: 12.5 – 7.7 – 9.4 – 8.9 S*: 32.8 – 12.9 – 10.3 – 11.1
Sleep-related Breathing Disorder	6.1 (4.7 – 7.8)	6.8 (4.3 – 10.9)	D: 7.8 – 5.0 – 7.2 – 4.7 S: 9.0 – 9.7 – 4.4 – 5.6
Comorbidity	8.1 (6.6 – 10.0)	18.8* (14.4 – 24.1)	D: 8.9 – 5.4 – 10.1 – 7.9 S*: 31.3 – 14.5 – 17.6 – 9.4

largest between-group difference was found for GSD prevalence and comorbidity as the second largest. The proportions of day workers versus shift workers with one or more of the six specific sleep disorders are 16.2% versus 28%. The fact that these proportions are much less than the sums of the six disorder-specific proportions (30.9% versus 61.2%; which would be the prevalence estimates of having any of the six disorders if no single individual had more than one sleep disorder) indirectly indicates that the six sleep disorders are strongly interrelated. This can be seen more directly in the comorbidity index, that is, the prevalence of two or more comorbid sleep disorders (Table 3). The "severity" of comorbidity is indicated by the correlation between the degree of comorbidity (the number of comorbid sleep disorders) and the height of the GSD factor score (Spearman's rho for shift workers 0.76, for day workers 0.62, both p < 0.01).

The prevalence of SWD symptoms among the shift workers was 12.4% (95%CI 8.9 – 17.1). For the sake of comparison, recognizing that a diagnosis of SWD must meet the ICSD-3 criterion of "association with shift work," the prevalence of SWD symptoms among the day workers was calculated as 8.1% (95%CI 6.6 – 10.0), that is, significantly lower than in shift workers (χ^2 = 4.41, df = 1, p < 0.05).

For the day workers as well as for the shift workers, the set of seven predictor variables (gender, age, partnership, children, insufficient sleep, napping, and M/E propensity) used in the logistic regression analysis, reliably distinguished between those with versus those without a general sleep disturbance (day workers: χ^2 = 76.56, df = 7, p < 0.001; shift workers: χ^2 = 51.02, df = 7, p < 0.001). For the day workers, significant odds ratio's (OR) were obtained for Insufficient sleep (OR 3.17, 95%CI 2.31–4.37) and Napping (OR 1.28, 95%CI 1.11–1.48), that is, these two variables had a significant effect on the odds ratio of a supra-threshold GSD score. For the shift workers, similar outcomes were observed for Insufficient sleep (OR 3.74, 95%CI 2.06–6.77) and Napping (OR 1.48, 95%CI 1.14–1.93). In addition, for shift workers only, Partnership (OR 0.49, 95%CI 0.25–0.93) and Age (OR 0.97, 95%CI 0.95–1.00) reached statistical significance (p < 0.05), indicating that absent partnership and younger age increased the odds ratio of a significant GSD score. Since partnership and age impacted the odds ratio of the presence of GSD in the shift workers only, their association with a general sleep disturbance was further examined.

Disordered sleep of shift workers varies across age and partnership

In order to evaluate possible interactions between the factors Day work versus Shift work and Age in association with disordered sleep, ANOVAs were computed for the GSD factor scores, the factor scores for the six specific sleep disorders, and the comorbidity index scores (the number of sleep disorder cutoff crossings). In addition to significant main effects of the Day work versus Shift work factor for all eight scores (p < 0.01), the results
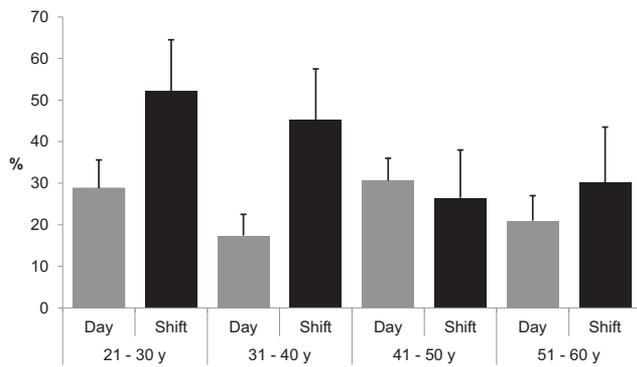
Figure 1. Prevalence rates of a general sleep disturbance among day workers and shift workers versus age. Error bars: 95% confidence intervals. Numbers of day workers versus shift workers for the four age groups were respectively: 191 versus 67, 259 versus 61, 307 versus 68, 214 versus 53.

showed a significant main effect of the Age factor for nearly all scores (except SBD) ($p < 0.01$); and a significant Day work versus Shift work x Age interaction for all scores except SBD ($p < 0.05$). Figure 1 displays this interaction expressed as GSD prevalence rates. Whereas the prevalence values for the day workers move up and down around a mean value of 25%, the shift workers show a systematic downward trend, from a high level of 52% in the first decade toward "normal" levels of approximately 28% for the third and fourth decades. Similar interactions were observed for most specific sleep disorders as well as the comorbidity index, as can be gleaned from the last column of Table 3.

Similar ANOVAs were run for the factors Day work versus Shift work and Partnership. In
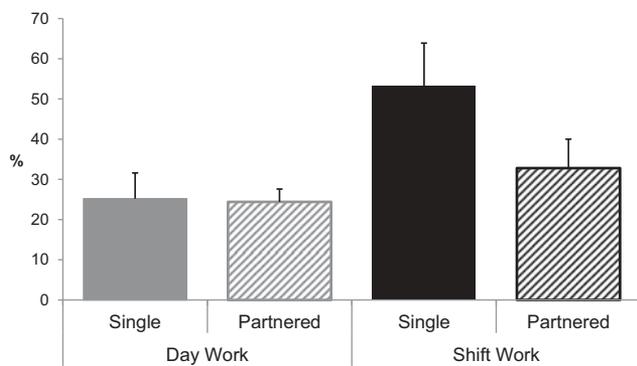

Figure 2. Prevalence rates of a general sleep disturbance among single and partnered day workers and shift workers. Error bars represent 95% confidence intervals. Numbers of single versus partnered workers among the day workers and shift workers were, respectively, 202 versus 770 and 77 versus 173.

addition to significant main effects of the Day work versus Shift work factor for all eight scores ($p < 0.01$), the results showed a significant main effect of Partnership for five scores (GSD, Parasomnia, CRSD, Hypersomnia, and Comorbidity index; $p < 0.05$), and a significant Day work versus Shift work x Partnership interaction for four scores (GSD, Parasomnia, Hypersomnia, and Comorbidity index; $p < 0.05$). This interaction, represented as GSD prevalence rates, is displayed in Figure 2. As was also evident from the significant interaction patterns for the other factor scores, the subgroup of single shift workers stands out clearly, with a higher prevalence rate than the partnered shift workers (53.2% versus 32.8%; $\chi^2 = 9.42$, df = 1, $p < 0.01$), whereas the single day workers did not differ from the partnered day workers. Between-group comparisons confirmed that not only the single shift workers but also the partnered shift workers had significantly higher GSD prevalence rates than both the partnered and the single day workers (all comparisons: $p < 0.05$).

Discussion

The present study adds to the findings of earlier research by showing that shift work, compared with permanent day work, is associated with a higher prevalence of clinically validated, ICSD-defined symptoms of nearly all main sleep disorders, that is, insomnia, circadian rhythm sleep-wake disorder, parasomnia, hypersomnolence, and leg movement disorder. Additionally, the prevalence of the symptoms of shift work disorder among shift workers was estimated at 12.4%, slightly above the average prevalence of the six specific sleep disorders (10.2%). Most noteworthy, the present study reveals that the comorbidity of sleep disorders (i.e. the prevalence of two or more comorbid sleep disorders) was more than twice as prevalent among shift workers (18.8%), than among day workers (8.1%) and that the "degree" of comorbidity correlated with a global sleep disturbance score (rho 0.76).

As verified in the present study, the conditions of shift work differ from those of day work by their larger variability in the timing of sleep, implying larger variability in the timing of light—dark exposure, meals and other synchronization

signals for the circadian clock. Consequently, shift work conditions obstruct the stable entrainment of the circadian system. The ensuing chronic state of flux of the circadian system has been shown to be conducive for a disruption of the structure and quality of sleep, as well as many other homeostatic brain systems involved in the regulation of metabolic, immune, cognitive, mental and many other vital functions (Smolensky et al., 2016; West & Bechtold, 2015). Most likely, it is this widespread disruption of circadian as well as sleep functions that is linked to the relatively high sleep disorder comorbidity as observed in the present study. In turn, sleep disorder symptoms appear to play a pivotal role in the propagation of comorbidity across a range of other health areas, as clearly illustrated in a study of comorbidity in psychopathology (Borsboom et al., 2011). Through a network approach to mental disorders and comorbidity, these authors showed that among the "small world" of 208 psychiatric symptoms as described in the Diagnostic and Statistical Manual of Mental Disorders-IV (APA, 1994), the symptoms of disturbed sleep had the highest "centrality index", i.e. had the most direct connections with the other symptoms (such as those belonging to anxiety and mood disorders). As the greatest common denominator, disturbed sleep served as the main "bridge" for the transmission of the effects from many symptoms to many other symptoms, thus propagating comorbidity. A similar perspective was outlined by Harvey (2008), arguing that insomnia may be a transdiagnostic process, a process that is common across several psychiatric (and sleep-related) disorders, and thus may be in a strategically important position to promote comorbidity. Thus, insomnia associated with chronically irregular working hours may sensitize the shift worker and induce a transdiagnostic process of "multi-organ failure," characterized by widespread comorbidity.

In support of the old saying that "shift work is only tolerable with the support of a partner" (Nachreiner, 1998), the present study showed that the odds ratio of a general sleep disturbance was significantly higher for single than for partnered shift workers (no interaction with gender was observed). Possible explanations could be that singles go without the social and moral support from a partner, may require more time for domestic activities, may have even more flexibility with their sleep schedule and consequently may have more difficulty to sleep well than their partnered peers. Nonetheless, even partnered shift workers were worse off than single (and partnered) day workers, emphasizing the independent, additional impact of shift work. Several studies have reported that, overall, partnered vsversus single individuals express the least sleep complaints, recognizing the modifying role of the quality of their relationship (Kent et al., 2015). This does not apply to the day workers of the present study, however. Apparently, as far as day work is concerned, the "partner-effect" is not significant when it comes to the clinically validated assessment of sleep disorders. Shift work conditions, on the other hand, do have a clinically significant impact and are likely to increase the risk of a widespread disruption of sleep, as suggested by the present study. As expressed previously, this may lead to a range of comorbid medical and psychiatric conditions, including metabolic syndrome, compromised immune function, cardiovascular disease, depression, and increased cancer risk (James et al., 2017; Wang et al., 2011; Wright et al., 2013). Speculatively, the results of the present study suggest that psychosocial support from a partner may mitigate the negative impact of shift work on sleep. This information may play a role in occupational health interventions aimed at reducing sleep problems and thus improving the resilience and tolerance of the shift worker (Bothelius et al., 2013; Järnefelt et al., 2014).

Another finding made it clear that the shift work versus day work condition interacted significantly with the factor "age", i.e. whereas the prevalence estimates for the day workers did not follow a systematic, positive, or negative trend across age categories, for the shift workers the prevalence estimates of most sleep disorders (except CRSD and SBD) tended to diminish across age categories. In particular, the groups of shift workers in their 20s and 30s distinguished themselves from day working peer groups by a wide-ranging disruption of their sleep. A most likely explanation for this age dependency can be found in the relatively large proportion of starters in these age categories, trying to cope with the

many challenges that are attached to shift work. Coping success or "the ability to adapt to shift work without adverse consequences" is also known as shift work tolerance (Andlauer et al., 1979; Saksvik et al., 2011). There is reason to assume that during the initial years of shift work – also referred to as "adaptation phase" (Koller, 1983) –, tolerant shift workers gradually differentiate from intolerant shift workers, as suggested by the results of a two-year prospective study (Lammers-van der Holst & Kerkhof, 2015). In a group of young novice police officers (age 20 – 44 years, mean 28 years), this study repeatedly assessed the cortisol awakening response (CAR), at baseline, when the subjects were naïve with respect to shift work, and at approximately 4, 14 and 20 months after their transition to rotating shift work. The CAR is considered a reliable marker of the activity of the HPA (hypothalamic—pituitary—adrenocortical) axis and its magnitude appears to be positively related to work stress, adverse prior day experiences and anticipation of forthcoming challenges (Chida & Steptoe, 2009; Elder et al., 2014). Over the first two years of shift work, a subgroup of the police officers showed a monotonically rising CAR, whereas another subgroup, after an initial increase during the first year, ultimately reverted to a smaller, baseline level cortisol response at approximately two years after commencing shift work. If the initial increase in the cortisol response marks the development of a chronic stress response, the subsequent reversal to baseline levels in the latter subgroup may be indicative of a process of recovery and/or adaptation, possibly the development of shift work tolerance. Intolerants, however, after they have experienced some difficult time in working shifts, are likely to make an effort to quit shift work and move to less risky shifts or jobs (Bamberger & Cafri, 2016). Thus, the process of self-selection, which may last for at least 10 years (Angersbach et al., 1980), will ultimately lead to an age-related increase (or smaller decrease) of the average level of health, known as "the healthy worker effect" (Knutsson & Akerstedt, 1992).

Limitations of this study include the cross-sectional design and the ensuing inability to make causal inferences, the use of subjective sleep reports and the potential common method bias, and the inability to conduct clinical interviews or employ objective sleep recordings. Positive aspects of this study include the use of a recent representative sample of the Dutch population, the use of a validated sleep disorder questionnaire, and the wide range of occupations represented in the data.

Declaration of interest

The author reports no conflicts of interest. The author alone is responsible for the content and writing of this article.

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